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GREEN SYNTHESIS, CHARECTERIZATION AND APPLICATION OF NANOPARTICLES

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ABSTRACT

Nanotechnology is a developing branch of pharmaceutical sciences wherein the particles extend in nanosizes and turn out to be more responsive when contrasted with their unique counter parts. In the past numerous years, the utilization of synthetic concoctions and physical strategies were in mould; however, the acknowledgment of their toxic impacts on human well-being and condition influenced serious world view for the researchers. Presently, green synthesis is the watch word for the combination of nanoparticles (NPs) by plants or their metabolites. This innovation is particularly compensating as far as decreasing the poisonous quality caused by the conventionally integrated NPs. In this review, we cover the perspectives by which metal particles can be integrated from green methods in the perspective of green methods utilized in the NPs combination. In the green strategies, plant metabolites and natural substances are utilized to orchestrate the NPs for the pharmaceutical and other applications. Some characterization methods are also reviewed along with applications of NPs.

KEYWORDS: Green synthesis; Nanoparticles; Metal nanoparticles; Green synthesis of nanoparticles.

I. INTRODUCTION

Nano is a metric measure of one billionth of a meter and co-vers a width of 10 atoms. In terms of comparison with real objects, an example that hair is 150,000 nanometers may begiven. The rapidly developing nanotechnology is the inter-disciplinary research and development field of biology, chemistry, physics, food, medicine, electronics, aerospace, medicine, etc., which examines the design, manufacture, as-sembly, characterization of materials that are smaller than100 nanometers in scale, as well as the application of minia-ture functional systems derived from these materials. It rep-resents the whole of development activities. As fir the nano-biotechnology, on the other hand, it is the result of a combi-nation of biotechnology and nanotechnology branches with a common combined functioning [1].

Nanotechnology is the branch of science which deals with the examination of materials in nanorange, generally between 1 to 100 nm. It is a science that works at the nanoscale and gives various focal points to the diverse fields of science like dentistry, pharmaceuticals and bio-engineering [2]. Green chemistry approach is significant for the future prospect of nanomaterials. This area of nanoscience should culminate in the development of safe, eco-friendly NPs and should have wide acceptance in the nanotechnology [3]. Solvents and reducing operators utilized for the reduction of the NPs have great effect on morphology of incorporated particles like their size, physicochemical properties, shape and this morphology impacts on the utilization of NPs. "Top down" and "bottom up" are the two unique methodologies for the amalgamation of NPs. In top-to-bottom approach, suitable bulk material is broken down into smaller fine particles by size reduction using various techniques like grinding, milling, sputtering, thermal/laser ablation, etc. while in bottom-to-top approach, NPs are synthesized using chemical and biological methods by self-assembly of atoms to new nuclei, which grow into nanosize particles while the "bottom-up" methods include chemical reduction, electrochemical methods and sonodecomposition [4]. Several advances report development of metal NPs that preclude surfactant and any other chemicals [5].

The synthesis of nanoparticles (NPs) can be performed using different methods, including physical, chemical, and biological techniques [6]. The NP synthesis by conventional physical and chemical techniques carries the risk of toxicity and environmental pollution as they release toxic by-products, which are potentially hazardous to the environment [7]. In addition to it, the NPs synthesized by such hazardous methods are unfit for the medical field due to the health-related concerns, particularly in clinical applications [8].

Although the conventional methods are suitable for the synthesis of large quantities of particles, in a lesser period of time, with defined sizes and shapes, these techniques have the drawbacks of being complicated, costly, inefficient, and out fashioned. The recent years have witnessed a growing interest in the nanosynthesis of environment-friendly particles without involving the production of toxic by-products as part of the synthesis process [9-11].

This task is achievable only through adopting environment-friendly synthesis procedures using biotechnology tools of biological nature that is described as safe and environmentally benign for nanosynthesis as an alternative to conventional physical and chemical methods [12, 13]. This concept has led to the approach of green technology or green nanobiotechnology. In general, the nanosynthesis procedures involving biological routes such as those which are based on microorganisms (viruses, bacteria, fungi, and algae), plants, plant extracts, or their by-products, for example, proteins, lipids, alkaloids, and flavonoids by applying different biotechnology tools and techniques [14,15].

The superiority of NPs synthesized by green technology to those produced by conventional methods is quite evident due to several features. For instance, green technology employs the use of cost-effective chemicals, less energy, and produces eco-friendly products, and by-products. The nanobiotechnology is more advantageous over other conventional procedures due to the fact the more components are available by the biological system for the synthesis of NPs [16,17].

By virtue of the rich biodiversity of biological systems, it is now possible to synthesize the bionanomaterials which are environment-friendly and have the potential to use in a variety of medical applications. Due to the synthesis of environment-friendly chemical products and by-products, the 12 principles of green chemistry are now considered as a reference guide in related research around the world [18]. Consequently, the green nanobiotechnology has now become a promising alternative route for the synthesis of biocompatible and stable NPs [19, 20]. In context to the importance of polyphenols including flavonoids of plant extracts in mediating the synthesis of metal NPs (MNPs), this review attempts to highlight and summarize the role of polyphenols in the synthesis of MNPs as described in recent literature.

Biosynthesis of NPs uses a bottom-up approach in which synthesis is performed by the application of reducing and stabilizing agents [21]. There are three main factors which are described for the biosynthesis of NPs based on a biological system: The choice of solvent medium, the choice of an eco-friendly and environmentally benign reducing agent, and the choice of a nontoxic material as a capping agent to stabilize the synthesized NPs [16].

II. COMPONENTS OF SYNTHESIS OF NPS

Distinctive natural specialists respond contrastingly with metal particles prompting the arrangement of NPs so the exact instrument for synthesis combination through organic methods shall have to be considered. For the most part, NPs are biosynthesized when the micro-organisms, plant extracts snatch target particles from their condition and afterward transform the metal particles into the NPs through the catalysts produced by the cells itself. It can be characterized into intra-cellular and extra-cellular amalgamation depending upon the area where NPs are framed Fig. 1

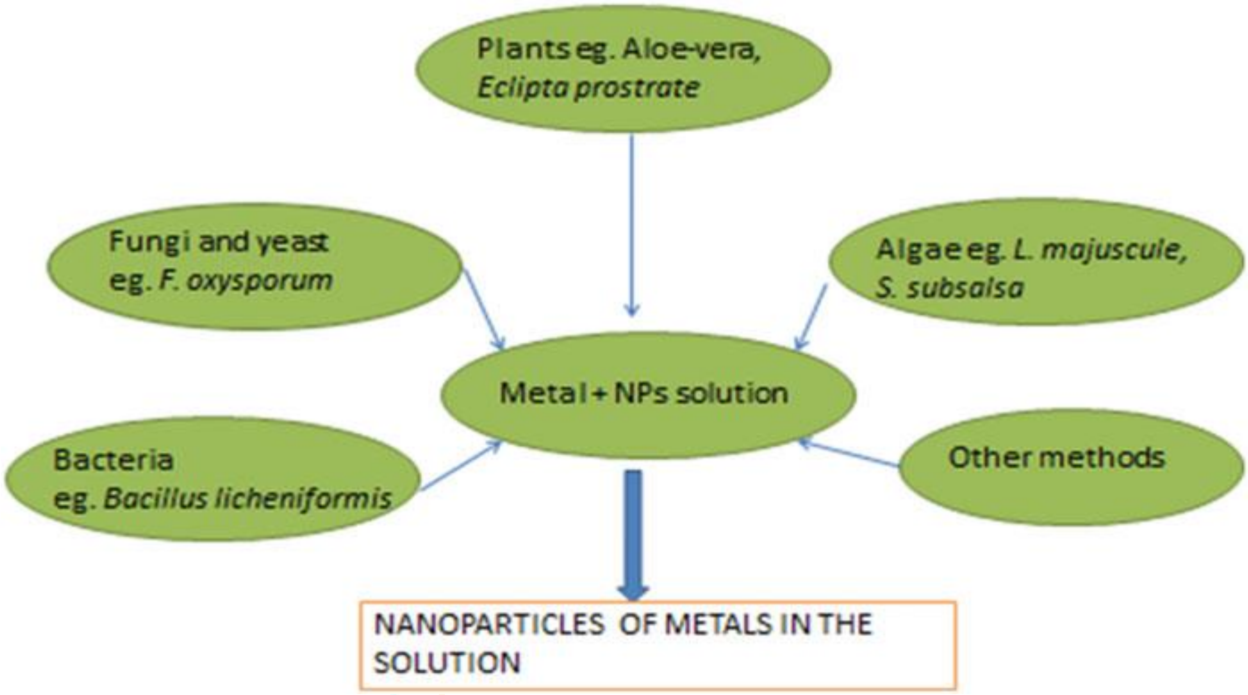

Fig. 1. Components of nanoparticles synthesis.

III. NANOPARTICLES AND THEIR PROPERTIES

The process of removing toxic and waste metals in the envi-ronment includes microorganisms, plants and other biologi-cal structures; achieved by means of oxidation, reduction or catalysis of metals with metallic nanoparticles.

Metallic nanoparticles produced by biological methods; are used in the biomedical field for purposes such as protection from harmful microorganisms, bio-imaging, drug transport, cancer treatment, medical diagnosis and sensor construction because of their unique properties such as being insulator, optics, antimicrobial, antioxidant, anti-metastasis, biocom-patibility, stability and manipulability. Metallic nanoparti-cles, which can be used in the industrial field due to their catalytic activity, are of great importance nowadays. Fig. 2 shows in detail where metallic nanoparticles obtained by biological methods are used [22, 23].

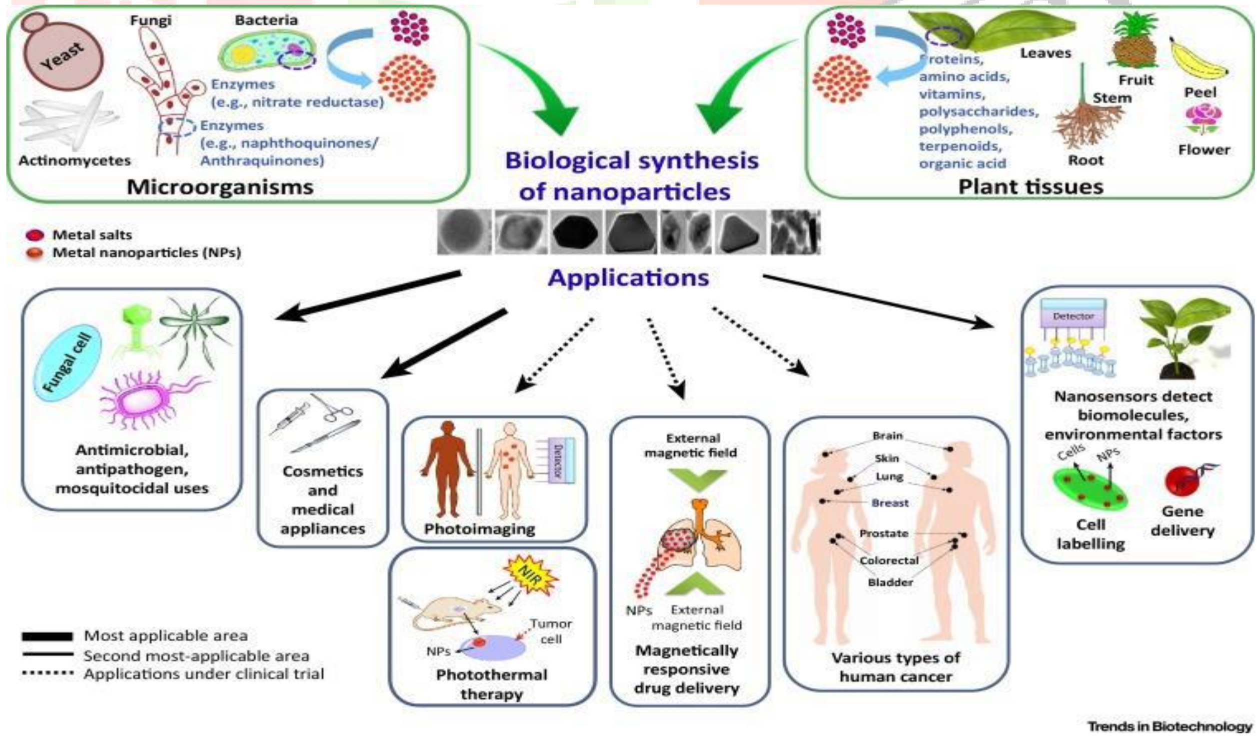

Fig. 2 Application areas of metallic nanoparticles synthesized by biolog-ical methods [23].

Nanomaterials, which are the mainstay of nanotechnology that serve our lives for many years thanks to the contributions of many sciences, can be classified according to their origins, dimensions and structural configurations. According to their origin;

nanomaterials are classified into two main groups: natural nanomaterials that are found in nature such as vi-ruses, proteins, enzymes and minerals, and artificial nano-materials which are not found in nature and require some processes for their production. According to their dimen-sions, nanomaterials are examined under four classes:

- nano-sized nanocrystals -also known as zero dimensions- which includes metallic and semiconductor nanoparticles.
- one-dimensional nanomaterials include nanowires, nano-bots, and nanotubes.
- two-dimensional nanomaterials such as nanocomposites and nanoplates;
- three-dimensional nanomaterials, bulkers.

According to their structural configurations, nanomaterials are studied under four main groups as metallic nanomateri-als, carbon based nanomaterials, dendrimers and composites. Fig.3 shows some types of nanoparticles used in nano-technology [24–26].

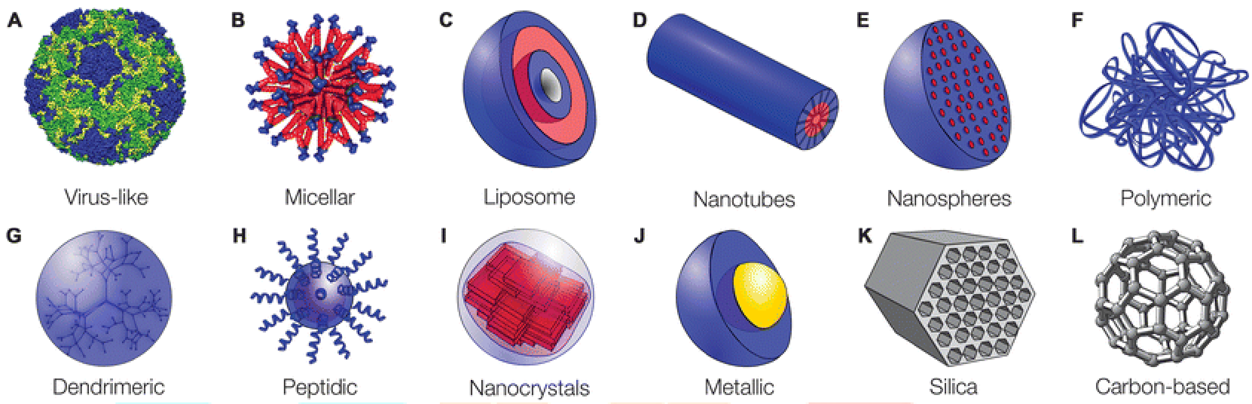

Fig. 3 Types of Nanoparticles [25]

The reason for the intense interest of scientists nowadays in nanoparticles is that nanoparticles can exhibit different prop-erties and functions than normal bulk materials. The most important factor that enables production of nanostructures in desired size, shape and properties and provides their usage in various fields is that the effects of classical physics are re-duced and the quantum physics becomes active. Other rea-sons for the different behavior of nanoparticles in physical, chemical, optical, electrical and magnetic behavior include the limitation of load carriers, size dependent electronic structures, increased surface / volume ratio, and other factors incurred by the unique properties of atoms [27].

IV. SYNTHESIS METHODS OF NANOPARTICLES

In the synthesis of nanoparticles, which can be natural or synthetic origin and exhibit unique properties at the na-noscale, two basic approaches that include various prepara-tion methods and are known from early times are used.

The first approach is the "top-down" method which calls for breaking down of solid materials into small pieces by apply-ing external force. In this approach, many physical, chemical and thermal techniques are used to provide the necessary en-ergy for nanoparticle formation.

The second approach, known as "bottom-up", is based on gathering and combining gas or liquid atoms or molecules. These two approaches have advantages and disadvantages relative to each other.

In the up-down approach, which is costlier to implement, it is impossible to obtain perfect surfaces and edges due to cav-ities and roughness that can occur in nanoparticles; whereas excellent nanoparticle synthesis results can be obtained by bottom-up approach. In addition, with the bottom up ap-proach, no waste materials that need to be removed are formed, and nanoparticles having smaller size can be ob-tained thanks to the better control of sizes of the nanoparti-cles. The classification of synthesis methods of nanoparticles is given in Fig.4 [28–30].

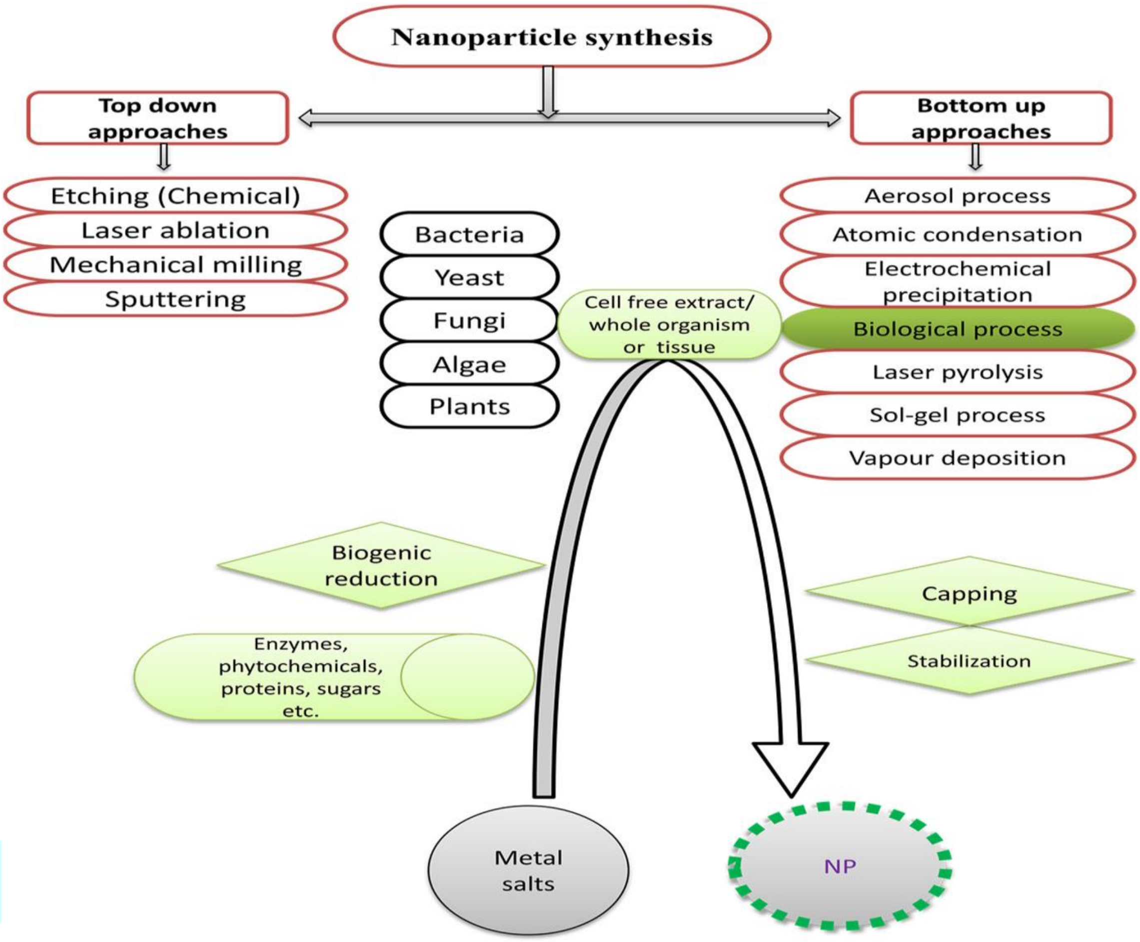

Fig. 4 Synthesis methods of nanoparticles.

The mechanical abrasion method, which is listed under the top-down approach, uses various ball mills to break down the material into particles and provides the production of nano-sized alloys, composites and semi-crystalline structures. Alt-hough this method is inexpensive, efficient and simple, it is susceptible to contamination caused by the balls [31].

V. GREEN APPROACH FOR SYNTHESIS OF NPS

Traditional methods are used from past many years but researches have proved that the green methods are more effective for the generation of NPs with the advantage of less chances of failure, low cost and ease of characterization [32]. Physical and chemical approaches of synthesizing NPs have posed several stresses on environment due to their toxic metabolites. Plant-based synthesis of NPs is certainly not a troublesome procedure, a metal salt is synthesized with plant extract and the response is completed in minutes to couple of hours at typical room temperature. This strategy has attracted much more attention amid the most recent decade particularly for silver (Ag) and gold (Au) NPs, which are more secure as contrasted with other metallic NPs. Generation of NPs from green techniques can be scaled up effortlessly and they are fiscally smart too. In light of their exceptional properties the greenly orchestrated NPs are currently favoured over the traditionally delivered NPs. Use of more chemicals, which are harmful and toxic for human health and environment, could increase the particle reactivity and toxicity and might cause unwanted adverse effects on health because of their lack of assurance and uncertainty of composition [33]. Green methods of synthesis are significantly attractive because of their potential to reduce the toxicity of NPs. Accordingly, the use of vitamins, amino acids, plants extracts is being greatly popularized nowadays[34].

VI. SYSTEMS FOR GREEN SYNTHESIS OF NPS

6.1 GREEN SYNTHESIS FROM ENZYMES

Well-defined structure and available purity of enzymes makes them preferable for green method of synthesis, e.g. Ag NPs were utilized to be combined by an enzyme induced growth

process on strong substrates in NPs synthesis. The enzymes were incorporated in polymer multilayer-assembled membranes through electrostatic interactions to develop the direct and "green" synthesis of bimetallic Fe/Pd particles in a membrane domain [35]. The generation of Au NPs utilizing extracellular amylase for the decrease of AuCl4 with the maintenance of enzymatic movement in the complex has been accounted for. Reaction surface strategy and central composite rotary design (CCRD) were utilized to upgrade a fermentation medium for the generation of a-amylase by Bacillus licheniformis at pH 8 [36]. A sulphite reductase enzyme purified from the E. coli by using ion exchange chromatography was used to develop a cell-free extract for the Au NPs synthesis having antifungal activity against human pathogenic fungi [37]. The nanoparticles (NPs) can be synthesized from agro-waste like Cocos nucifera coir, corn cob, fruit seeds and peels, wheat and rice bran, palm oil, etc. These compounds are rich in biomolecules like flavonoids, phenolic and proteins that could act as reductive agent for the synthesis of NPs [38]. In a reported method of reduction of NPs with beet juice the authors found that on decreasing the amounts of beet juice, larger size Ag NPs were obtained, which also showed much greater catalytic activity and stability than those prepared with NaBH4 for the transformation of 4-nitrophenol to 4-aminophenol [39]. Green tea extracts were used to get bimetallic NPs of Fe/Pd for the first time as the extracts of green tea can act as both reductive as well as capping agent also [40]. Au NPs functionalized mediated with a redox enzyme can perform as an electron transmitter between the biocatalyst and the electrode and accordingly give a hybrid electrically dynamic biomaterial that can be utilized in different sensors applications [41].

6.2 GREEN SYNTHESIS FROM VITAMINS

Green combination of Ag and palladium nano-spheres, nanowires and nano-rods by utilizing vitamin B2 (as reducing and capping agents) has been reported. The vitamin B2 is used as the reducing agent for the synthesis of the nanowires and nanorods. This is a unique approach, in the field of green nanotechnology that suggests the use of natural agents in advancement of this field, for example their impact on different tumour cells [42]. Ascorbic acid is used as capping and reducing agent along with the chitosan as stabilizing agent due to the property of chitosan bonding with metal ions, NPs concentration is directly dependent on chitosan concentration used [43]. A simple method of developing NPs of uniform sizes produced by using ascorbic acid as the reducing and capping material is reported [44]. Water-soluble anti-oxidative agents like ascorbic acid further seem to be responsible for the reduction of Ag NPs in Desmodium triflorum. During glycolysis, plants produce a large amount of Hþ ions along with NAD and acts as a strong reducing agent; this seems to be beneficial in the formation of Ag NPs [45].

6.3 MICROWAVE-ASSISTED SYNTHESIS

Nanowires, tubes and dendrites can be produced by altering the parameters like surfactants and metallic precursors and solvent. Spherical shaped nanomaterials can also be produced by this method [46]. Carboxyl methyl cellulose sodium is utilized as reducing and capping specialist for Ag NPs synthesis. Contrasted with general heating treatment, MW union is supportive of homogeneous heating and simple nucleation of noble metal NPs [47]. A fast NPs generation method (within few seconds) for the synthesis of Au, Ag, palladium and platinum in aqueous medium by MW irradiation method at 50 W is reported by using red grape pomace as a reducing agent [48].

6.4 BACTERIA AND ACTINOMYCETES

Shivaji et al. developed Ag NPs stable in dark place for 8 months by using cell-free culture supernatants of psychrophilic bacteria Pseudomonas antarctica, Pseudomonas proteolytica, Pseudomonas meridiana, Arthrobacter kerguelensis, Arthrobacter gangotriensis, Bacillus indicus and Bacillus cecembensis [49]. Simon Ag suggested that particular gene is responsible for Ag resistance in bacteria and these bacteria can replace the use of Ag in case of burn to reduce chances of the Ag toxicity [50]. Silver nano-crystals of different compositions were successfully synthesized by Pseudomonas stutzeri AG259 [51] Fig.5.

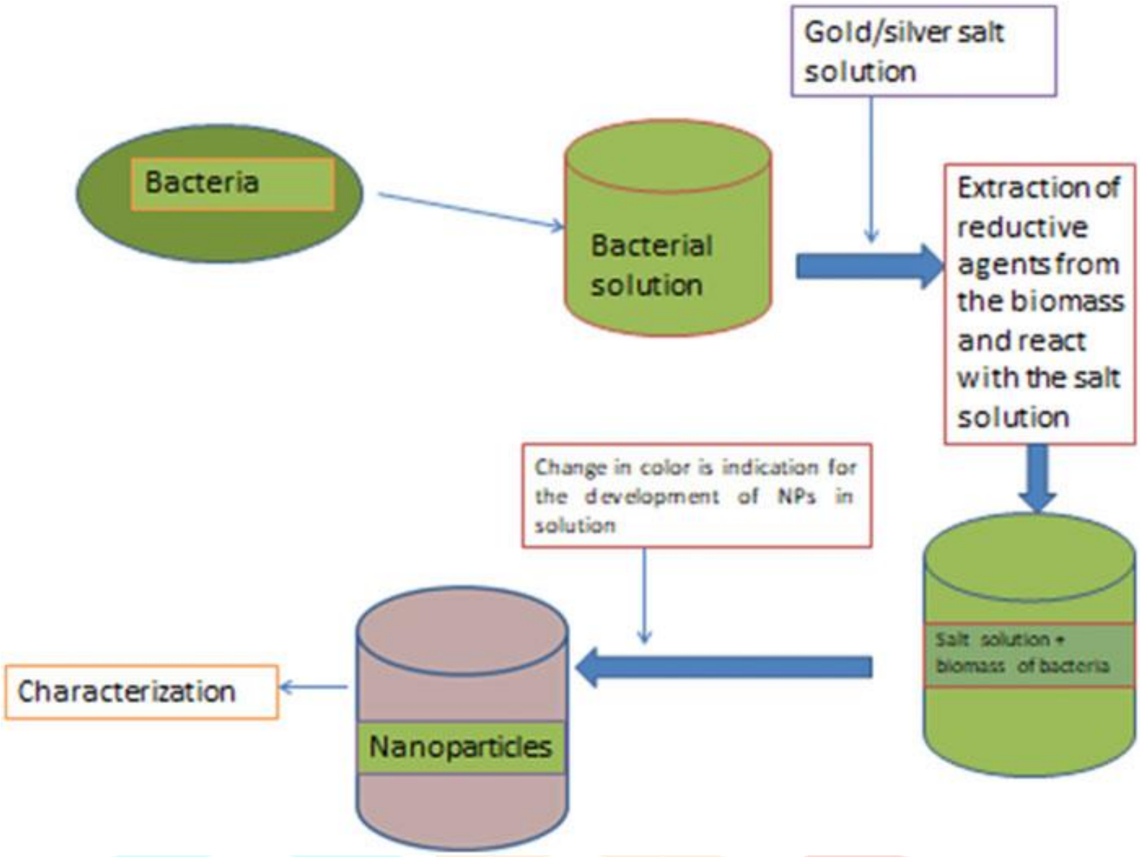

Fig.5 Bacterial synthesis of nanoparticles.

6.5 YEASTS AND FUNGI

Silver nitrate was transformed into Ag oxide, forming welldispersed NPs, by the action of F. oxysporum metabolically. The introduction of Ag particles to F. oxysporum, brought about the release of nitrate reductase ensuing development of exceedingly stable Ag NPs in solution [52]. Nano-platinum has been incorporated by the culture filtrate of Alternaria alternata, and the platinum NPs were characterized by various spectroscopic investigations (particle size 2–30 nm, spherical and triangular found the O–H stretching, C–H stretching (proteins and other organic residues), amide I (polypeptides) amide III bands (the random coil of protein)) [53]. The synergistic action of selenium NPs and the fungal C. albicans was observed after combination of selenium NPs with chitosan and fungi was used as reductive agent [54]. Extracellular biosynthesis of AgNPs from Ag nitrate solution is reported by the fungus Trichoderma viride [55]. Fusarium oxysporum has been used to develop very stable Ag NPs of sizes 5–15nm [56].

6.6 ALGAE

Cyanobacteria and eukaryotic green development genera, for instance, L. majuscule, S. subsalsa, R. hieroglyphics, C. vulgaris, C. prolifera, P. pavonica, S. Platensis and S. fluitans can be used as cost effective materials for bio recovery of metal out of the liquid courses of action [57]. Uma Suganya et al. inspected green synthesis of Au metal NPs by using blue green development. The product of AuNPs was a direct result of the reduction of Au3þ particles of chloroauric destructive to Au0 by S. platensis protein [58].

6.7 PLANTS AND PHYTOCHEMICALS

Combination of NPs utilizing plants is extremely practical, and in this manner can be utilized as a monetary and important option for the expansive scale generation of NPs [59]. In an exploration of different antioxidant constituents of the extracts of blackberry, blueberry, turmeric and pomegranate, the pomegranate was found to have the ability to produce more uniform size and shape NPs of Au and Ag in the range of 20–500 nm. These NPs could be used for the management of cancer and the antioxidant therapy [60]. F. herba isolate was used to reduce the platinum compound, the closeness of hydrogen and carbonyl in polyphenolic compound mainly goes about as fixing expert for metal particles [61]. Formation of NPs could be completed in salt solution within short duration of time depending on the nature of plant extracts; the main reason being the concentration of the extracts, metal salt, pH and contact. It has been discovered

that decrease of AgNO3 to AgNPs by dihydroquercetin, quercetin and rutin prompted the development of an intensive surface plasmon resonance (SPR) band, which suggests reduction of this constituent [62]. Kou and Varma reported a simple, green and fast (complete within 5 min) approach for the construction of Ag NPs by MW irradiation using beet juice as a reducing reagent. The prepared material displayed good photocatalytic activity for the degradation of methyl orange (MO) dye [63].

VII. METALS SYNTHESIZED FROM GREEN SYNTHESIS

7.1 COPPER (Cu) AND COPPER OXIDE (CuO)

Colloidal heat combination process is utilized to get CuO nanomaterials. The incorporated CuO was decontaminated and dried to acquire distinctive sizes of the CuO NPs [64]. Manoj et al. reported a method of developing a bio-sensor for the detection of nitrite ions in the medium, this method includes use of CMC as substrate for developing highly stable and sensitive nanocomposite of Cu [65].

7.2 ZINC OXIDE (ZnO)

Cassia auriculata blossom extract was utilized for the treatment of fluid arrangement of Zn(NO3)2 to combine stable ZnO NPs with normal size extents 110–280nm [66]. Alijan et al. observed the normal size of ZnS NPs to be 8.35nm while being exceptionally steady and overwhelmingly spherical ZnS NPs were orchestrated utilizing a characteristic sweetener glycoside (250–300 times sweeter than sucrose) in the aqueous rough concentrate of Stevia rebaudiana that went about as a great bio-reductant [67]. ZnO and Ag/ZnO NPs obtained through green synthesis are also useful in clinical antimicrobial wound-healing bandages [68].

7.3 CERIUM OXIDE (CeO_2)

Rocca et al. investigated the antioxidant effects of CeO2 NPs as a potential pharmaceutical approach for the treatment of obesity [69]. Moreover, besides possessing fast electron transfer kinetics, CNP is an excellent co-immobilization material for a variety of enzymes such as cholesterol oxidase, glucose oxidase and horseradish peroxidase [70]. Extract of Gloriosa superba leaf displayed excellent antibacterial properties; CeO2 NPs were of spherical shape with an average size of 5 nm [71]. Miri and Sarani conducted the cytotoxic investigation of cerium oxide NPs (CeO2-NPs) biosynthesized utilizing the aqueous extracts of ethereal parts of Prosopis farcta, and demonstrated that the biosynthesized particles were consistently and roundly formed with a size of around 30 nm [72].

7.4 CADMIUM SULPHIDE (CdS)

Cadmium sulphide quantum dots were developed from the plant synthesis of CdS NPs by Biomass of Fusarium oxysporum get dots of sizes ranges between 2–6nm [73]. A MW assisted method was used to produce Cds NPs of Trichoderma harzianum, a common biofungicide, it produced 3–8 nm spherical wurtzite CdS NP after 72 h of biomass incubation with cadmium chloride and sodium sulphide [74]. In a study of Escherichia coli and Klebsiella pneumonia (isolated from the stool of healthy volunteer's samples) it was found they possess the ability to produce CdS NPs. This kind of microorganisms can be used for synthesis of NPs and heavy metal absorption for detoxification of environment [75].

7.5 SILVER AND GOLD

Silver and Au NPs have been broadly considered for use in applications in a different scope of fields (e.g. optoelectronics, catalysis, sensing, medicine, etc.). Honey can increase the reduction speed as the concentration is increased in the NPs solution, NPs formed with the mediation of honey are having special characteristics such as bio-sensing, anticorrosive, catalytic and antimicrobial activity [76]. Francis et al. prepared Au and Ag NPs using M. glabrata leaf extract from their respective metal salt precursors by MW assistance. They open a new area for water purification because of their tremendous antimicrobial activity inhibiting pathogenic microorganisms like Bacillus pumilus, Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli, Aspergillus niger and Penicillium chrysogenum [77]. An economic method was developed to synthesize Ag NPs of smaller then 140nm sizes by using two different microorganisms Bacilus subtilus 10833 and Bacilus amylococus 1853, problem with this method was lake of reproducibility, time consuming process (48 h) and impurity issue at some extent [78]. Shen et al. revealed an investigation in which they reported combination of Au NPs from various microorganisms. They compared three different cell free extracts, i.e. bacteria Labrys sp., yeast Trichosporon montevideense, and filamentous fungus Aspergillus sp., selected for AuNPs and at the end of experiment they reported the average sizes of the NPs were 18.8, 22.2 and 9.5 nm, respectively. They found that the fungus showed better results as compared to others [79]. Gonnelli et al. described gold NPs (AuNPs) from concentrates of Cucurbitapepo L. takes off. The examination was completed at various plant ages, from one to four months, and the generation of NPs (in term of size, shape and yield) was dependent on the concentration of chlorophyll and carotenoids in the extracts [72]. A green combination of Ag NPs was created,

utilizing a low-toxic system of microemulsion and nanoemulsion with castor oil as the oily phase, Brij 96V and 1,2-hexanediol as the surfactant and co-surfactant individually. Geranium (P. hortorum) leaf aqueous extract was utilized as a reducing specialist [80].

VIII. CHARACTERIZATION

After the synthesis of NPs it is must to ponder the morphology and other conformational subtle elements by utilizing different spectroscopic strategies. The most widely utilized systems are: UV–vis absorption spectroscopy, X-ray diffraction (XRD), Fourier transmission infrared (FTIR) spectroscopy, dynamic light scattering (DLS), energy dispersive X-ray examination (EDAX), scanning electron microscopy (SEM), transmission electron microscopy (TEM) and so on Fig.6

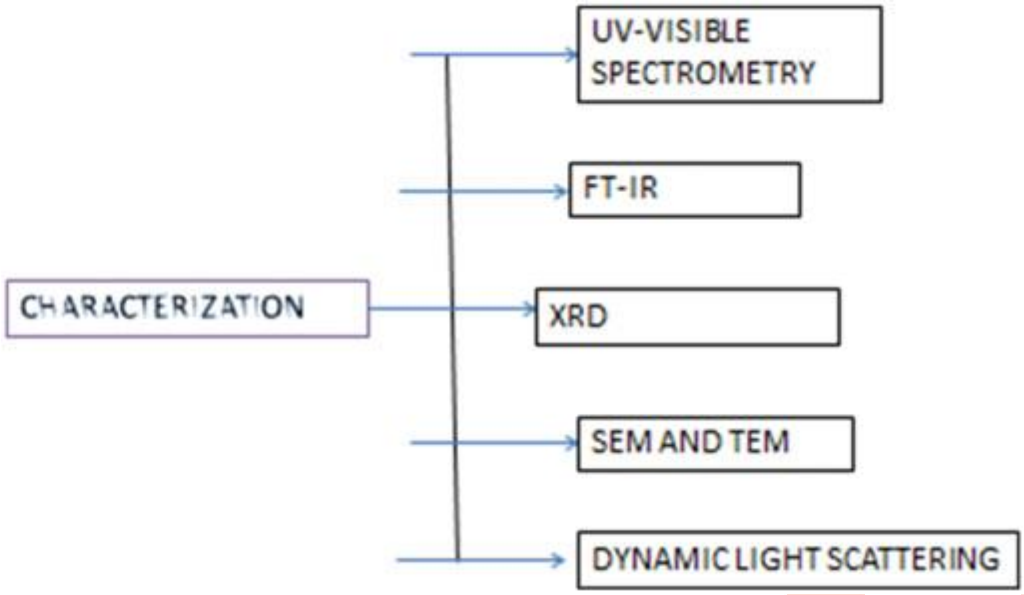

Fig.6 Characterization techniques.

8.1 UV–VISIBLE SPECTROSCOPY

Arrangement of NPs from UV–visible spectroscopy can be studied due of their surface plasmon reverberation assimilation band because of the consolidated wavering of conduction band electrons on the surface of metal NPs in reverberation with light wave. Subhapriya and Gomathipriya reported the bio-reduction of Ag nitrate to Ag NPs and estimated occasionally by UV–visible spectroscopy [81].

8.2 FT-IR

FT-IR spectroscopy is conducted to discover data about the diverse utilitarian gatherings from the pinnacle positions in the range, FTIR spectroscopy is used to examine the property of functional groups or metabolites present on the surface of NPs, which might be responsible for reduction and stabilization of NPs and information about capping and stabilizing of the NPs [82].

8.3 HIGH RESONANCE SEM

New age of high-resolution SEM (HRSEM) permits a determination superior to anything 1 nm, moving towards the determination of TEM. With this procedure, it is conceivable to break down collaborations, for example, the adsorption and take-up of metallic NPs by cells. TEM and SEM examination clarifies the morphology and size of the resultant NPs. TEM results uncover that the Ag NPs are round and monodisperse.

8.4 XRD SPECTROSCOPY

X-ray diffractograms of nano-materials give an abundance of data from phase creation to crystallite estimate, from cross section strain to crystallographic introduction, XRD is non-contact and non-destructive, which makes it ideal for in situ studies [83]. Other techniques for characterization of NPs are EDS and DLS, the energy dispersive spectroscopy (EDS) is used to separate the characteristic X-rays of different elements into an energy spectrum, is used for detection of elemental composition of metal NPs. Dynamic light scattering analysis of incident photons is used to determine the surface charge and the hydrodynamic radius of the NPs.

IX. APPLICATIONS OF GREEN NANOTECHNOLOGY

Nanoparticles are also used in routine life in following ways:

9.1 SPORTS EQUIPMENT

Nanoparticles are added to materials to make them stronger whilst often being lighter. They have been used in tennis rackets, golf clubs and shoes.

9.2 NANOPARTICLES IN DYES AND VENEERS

Dyes and Veneers industry is rising gradually round the orb. Dyes and Veneers not only assist the determination of embellishment but also a means to shield treasured metals and buildings from deterioration. Nanotechnology in Dyes and Veneers talents to justify all desire possessions [84]. New paint skill contests bacterial and fungal evolution with nanoscale Ag. AgNPs in wall paint thwart the creation of mold exclusive buildings and the evolution of algae on external walls. Ag inhibits the several stages of cell breakdown; it abolishes a wide range of germs and makes it grim for germs to develop confrontation [85]. NPs are so minor that they can establish themselves faithfully sufficient and pledge organized to form a molecularly wrapped sur-face. The presence and practicality of nanoparticles takes many benefits like healthier surface appearance, decent chemical confrontation, informal to clean, shielding effect against fog, high performance coating, self-cleaning etc.

9.3 NANOPARTICLES IN TEXTILES AND CLOTHING

Within the last span, Nanotechnology based progress in textile laments, yarns, and fabric finishing have directed to the growth of numerous new and enhanced textile products. Freshly, a nano-based technology has been developed by swiss company Scholler to yield a new brand of fabrics called soft-shells, which is a functional stretch multi-layer fabric. Furthermore, several antimicrobial textile treatments are presently being fashioned that can play very noteworthy characters in fortification against a wide range of physical/chemical/biological terrorizations. Nano-based textile composite materials encompass another gifted sector, which is leading the advances of novel materials for engineering applications.

9.4 NANOPARTICLES IN COSMETICS

Nanotechnology and nanomaterials are found to be useful in several cosmetics products like conditioners, make up, suntan lotion and hair care products. Cosmetics are applied to the stratum corneum, known as dead cells, which is used to shield the body from the in-filtration of foreign materials including cosmetics [86]. The appearance of skin can be improved by nanocarrier system which empowers the cosmetic agents to breach the skin layers where they stimulate skin metabolism. To increase the concentration of active agents in cosmetics liposomes (vitamin A, E and CoQ10) are used [87].

9.5 NANOPARTICLES IN NUTRITION SCIENCE

Nanotechnology has become one of the utmost hopeful technologies to transfigure conservative food science and the food industry. Nanotechnology-assisted dispensation and packaging has evidenced its capability in food systems. Nanoparticles can be produced by different groundwork technology with different physical possessions that could be used in food. Present scientific regulation of food nanotechnology is branded by frequent worries concerning risk characteristics. Functionality of food nanotechnology determines its range of applicability. Food nanotechnology can affect the bioavailability and nutritional value of food based on its functions. The biological properties of nanomaterials are mainly dependent on their physicochemical parameters. The main association of nanotechnology and food industry is that nanotechnology is enhancing food security, refining flavor, increasing storage life, nutrient delivery and serving functional foods [88].

9.6 CATALYTIC USE OF NANOPARTICLES

Catalysis is essential use of metal NPs. Because of the large surface area of nanoparticles, it shows effective potential as a catalyst. Several investigators suggested that metal nanoparticles are very useful catalysts due to the reason that substantial number of atoms remains at the surface, so these surface atoms is available for the chemical transformation of substrate. Different nanomaterials are used as a catalyst including metals and its oxides, sulfides and silicates. Catalyst activity can be defined by Turn over Number (TON) and its efficiency by Turn over Frequency (TOF) [89].

X. CONCLUSION

The emerging threats related to the toxic and hazardous nature of the conventional methods of NP synthesis have led to the plant extracts-mediated synthesis of MNPs. The green nanosynthesis approach thus adopted is cost and time effective, and environment-friendly with the potential to easily scale up the product. Such a non-toxic approach is especially desirable to synthesize the NPs that must not be toxic if they are destined for the therapeutic applications. The NPs of controlled size and shape can be synthesized using various plant extracts of which the polyphenols, including flavonoids, are considered as the most active bioreductants of metal ions. The MNPs synthesized using natural polyphenols and flavonoids have shown a number of biomedical applications, including their therapeutic activity against various ailments.

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